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Project Number: 9980-03401 (M91-424)

TITLE: Composition of Waters from the Research Drill Hole at Summit of Kilauea Volcano and of Selected Thermal and Non-Thermal Groundwaters, Hawaii

AUTHOR: Robert I. Tilling, Blair F. Jones

CONTENTS: 28 p., _____ over-size sheets (i.e., larger than 8 1/2 by 14 inches)

Map Scale: _____

1 diskette in Microsoft word, v.4.0

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Open-File Report 91-133-A and -B. Composition of waters from the research drill hole at summit of Kilauea Volcano and of selected thermal and non-thermal groundwaters, Hawaii, by Robert I. Tilling and Blair F. Jones. 1991. 27 p.

This report presents analytical data--chemical and isotopic (δO^{18} and δD)--and other information on water samples collected during the period 1973-1976 from a 1262-m (4137-ft) deep research borehole at the summit of Kilauea Volcano, Hawaii. To facilitate comparison of the summit-borehole data, analytical data on selected water samples from the State of Hawaii (mostly from the Island of Hawaii) are also presented. This report is issued both as paper copy (Open-File Report 91-133-A) and as 3.5-inch diskette (Open-File Report 91-133-B). The diskette version requires an Apple II or Macintosh II; the text, which includes inserted graphics (Figs. 1-3), is in Microsoft Word, v. 4.0.

U.S. DEPARTMENT OF THE INTERIOR

U.S. GEOLOGICAL SURVEY

Composition of Waters from the Research Drill Hole at Summit of Kilauea Volcano and of Selected Thermal and Non-Thermal Groundwaters, Hawaii

by

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and

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Open-File Report 91-133-A

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INTRODUCTION

Kilauea, on the Island of Hawaii (Fig. 1), is the one of the most active volcanoes in the world, and the current eruption on its east rift zone, which began in January 1983, continues unabated (Wolfe, 1988; Moulds and others, 1990) as of this writing (January 1991). In February 1972, George V. Keller (Department of Geophysics, Colorado School of Mines) submitted a proposal to the National Science Foundation (NSF) to drill a

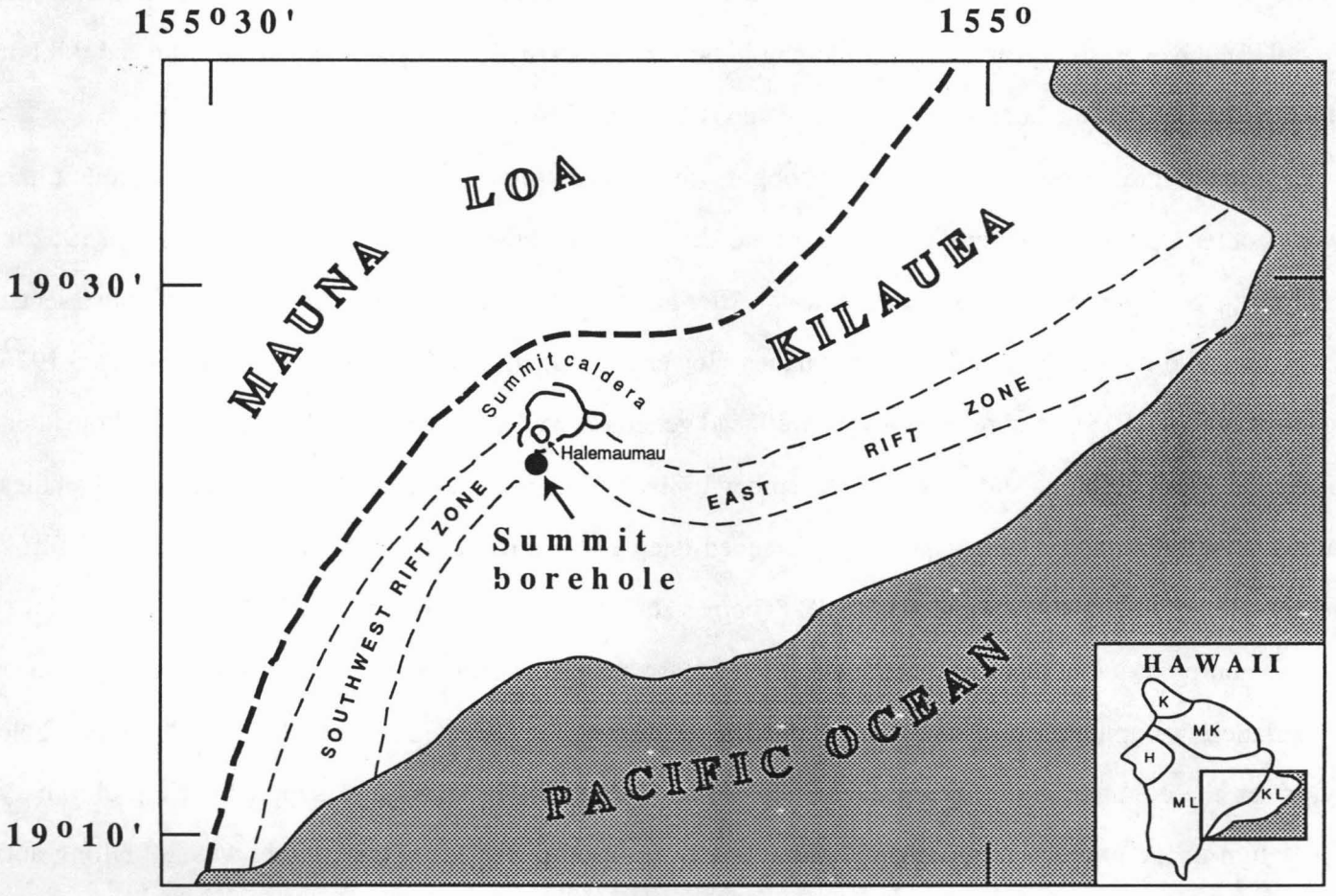

Figure 1. Sketch map showing the location of the research borehole at the summit of Kilauea Volcano, Hawaii, drilled during the period April-July 1973, and neighboring Mauna Loa Volcano. Kilauea is the southeastern-most and youngest of the five volcanoes that make up the Island of Hawaii (see inset): K, Kohala; MK, Mauna Kea; ML, Mauna Loa; H, Hualalai, KL, Kilauea. Beginning in 1976, a number of deep geothermal exploration and scientific observation wells have been completed in the lower part of Kilauea's east-rift zone (see Thomas, 1987; Thomas and others, 1990).

research borehole to study the hydrothermal convection cell above Kilauea's magma reservoir. This proposal was funded by the NSF, and during the period 6 April-9 July 1973 a 1262-m (4137-ft) deep hole (19° 23.7' N, 155° 13.3' W) was drilled at the summit of the volcano, 1.1 km south of Halemaumau Crater (Fig. 1). Staff members of the U.S. Geological Survey's (USGS) Hawaiian Volcano Observatory worked collaboratively with investigators from the Colorado School Mines during and following the drilling project. Preliminary results of the drilling and related studies were described in the following works and/or pertinent references contained therein: McMurtry and others (1977), Murray (1974), Keller and others (1974a,b; 1976, 1979), and Zablocki and others (1974, 1976). Over a three-year period, beginning in September 1973, 15 water samples were collected (all but two by the USGS) from the borehole for chemical and isotopic analysis.

Although unrelated to the Colorado School of Mines 1972 proposal for drilling at Kilauea's summit, the Hawaii Geothermal Project, under the auspices of the University of Hawaii (Honolulu), was launched in 1972 to develop geothermal power on the Island of Hawaii. After preliminary geologic and geophysical studies to select a drill site, an 1,996-m-deep well (HGP-A) in Kilauea's lower east-rift zone (LERZ) was completed in April 1976 (Shupe and others, 1978). A three mega-watt wellhead generator was installed at this site in 1981 and operated for eight years before it was shut down in December 1989. Through the 1980s, interest in geothermal studies remained strong, and a number of privately financed deep exploration wells and publicly funded scientific observation holes have been drilled in the LERZ (Thomas, 1987; Thomas and others, 1990).

The purpose of this report is three-fold: (1) to release heretofore unpublished compositional data on water above Kilauea's summit reservoir and other Hawaiian water samples collected in connection with the borehole study, given the continuing strong interest in geothermal studies in Hawaii; (2) to supplement a preliminary interpretation of the observed temporal variations in composition of the summit-borehole waters (Tilling and Jones, 1990); and (3) to provide a reference dataset for continuing studies.

SAMPLING AND TEMPERATURE MEASUREMENT

In-hole temperature logs suggested that drilling-induced thermal disturbance of the summit borehole had largely, or possibly completely, dissipated by early August 1973, about a month after cessation of drilling on 9 July 1973 (Keller and others, 1979, Fig. 14). However, to allow additional time for total elimination of drilling effects, sampling (Fig. 2) was not initiated until 4 September 1973, nearly two months after well completion .

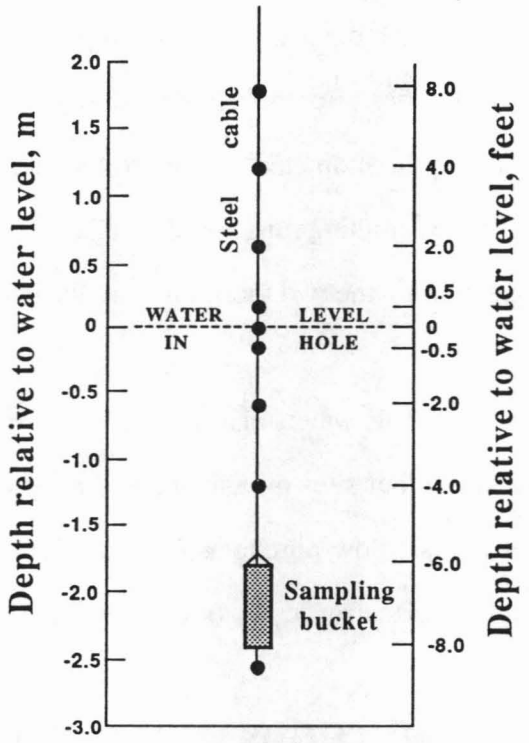

Figure 2. Diagram showing a typical configuration used to sample water from the top of the water column (i.e., the regional water table) in the summit borehole; the dots along the cable indicate the positions of maximum thermometers used to determine the temperature profile in the immediate vicinity of the water table (see Figure 3). The water level in the hole, arbitrary designated "0" for convenience, is about 488 m (~ 1,600 ft) below the ground surface, with little measurable variation. Seasonal fluctuation in the water level possibly is suggested by the observation that the level on 08/27/74 (summer "dry" season) was about 4 feet (~ 1.2 m) lower than that on 02/21/74 (winter "wet" season). Geophysical surveys indicate that the water level in the hole coincides with the regional high-level water table at Kilauea's summit (Jackson and Lenat, 1989; Jackson and Kauahikaua, 1990).

Except for two samples, all the waters from the Kilauea summit borehole (Table 1; **all tables are given at the end of report**) were collected by means of a cylindrical bucket (~ 8 cm I.D., ~ 60 cm length) attached to a steel cable of known length and marked at known depth intervals (Fig. 2). The sampling bucket was lowered and raised manually by means of a sheave positioned near the borehole opening. All but two of the samples were taken from a horizon about 2 m below the top of the water column, which marks the local water table at about 488 m (1,600 ft) below ground surface. Two samples--numbers 50 and KBW-8 (Table 1)--were obtained from a level about 30.5 m (~ 100 ft) below the water table using a thief sampler; attempts to collect deeper and hotter samples failed because of mechanical difficulties. Borehole temperatures in a 4.5-m interval bracketing the water table, were measured by maximum-reading thermometers affixed to the cable and bucket as shown in Figure 2; temperature profiles obtained in some of the sampling runs are illustrated in Figure 3. The temperatures shown in Table 1 are the higher of readings registered by the two thermometers located immediately above and below the sampling bucket (Fig. 2).

To place the study of the summit borehole waters in a regional context, we also analyzed thermal and non-thermal water samples collected at various other sites on Kilauea and neighboring Mauna Loa Volcano. These samples include rainfall, perched water in shallow boreholes (< 111 m), water from drilled wells, water from intermittent streams, and water ponded in a permafrost crack (see Table 2).

ANALYTICAL METHODS AND DATA TABLES

Chemical analyses of the water samples collected **after** well completion were made at a laboratory of the Water Resources Division (WRD), U.S. Geological Survey, located at Reston, Virginia, using techniques similar to those described in Skougstad and others (1979). Hydrogen and oxygen isotopic compositions of these same samples were determined in WRD's stable-isotope laboratory supervised by Tyler B. Coplen; the analytical procedures used are described in Coplen (1973). In addition, selected minor and trace elements of several samples (water, drilling mud, slurries), collected **during** the drilling, were determined by instrumental neutron-activation analysis (INAA) at the USGS laboratory in Denver, Colorado, using techniques adapted from those outlined in Zielinski and others (1977) and in Dodge and others (1982).

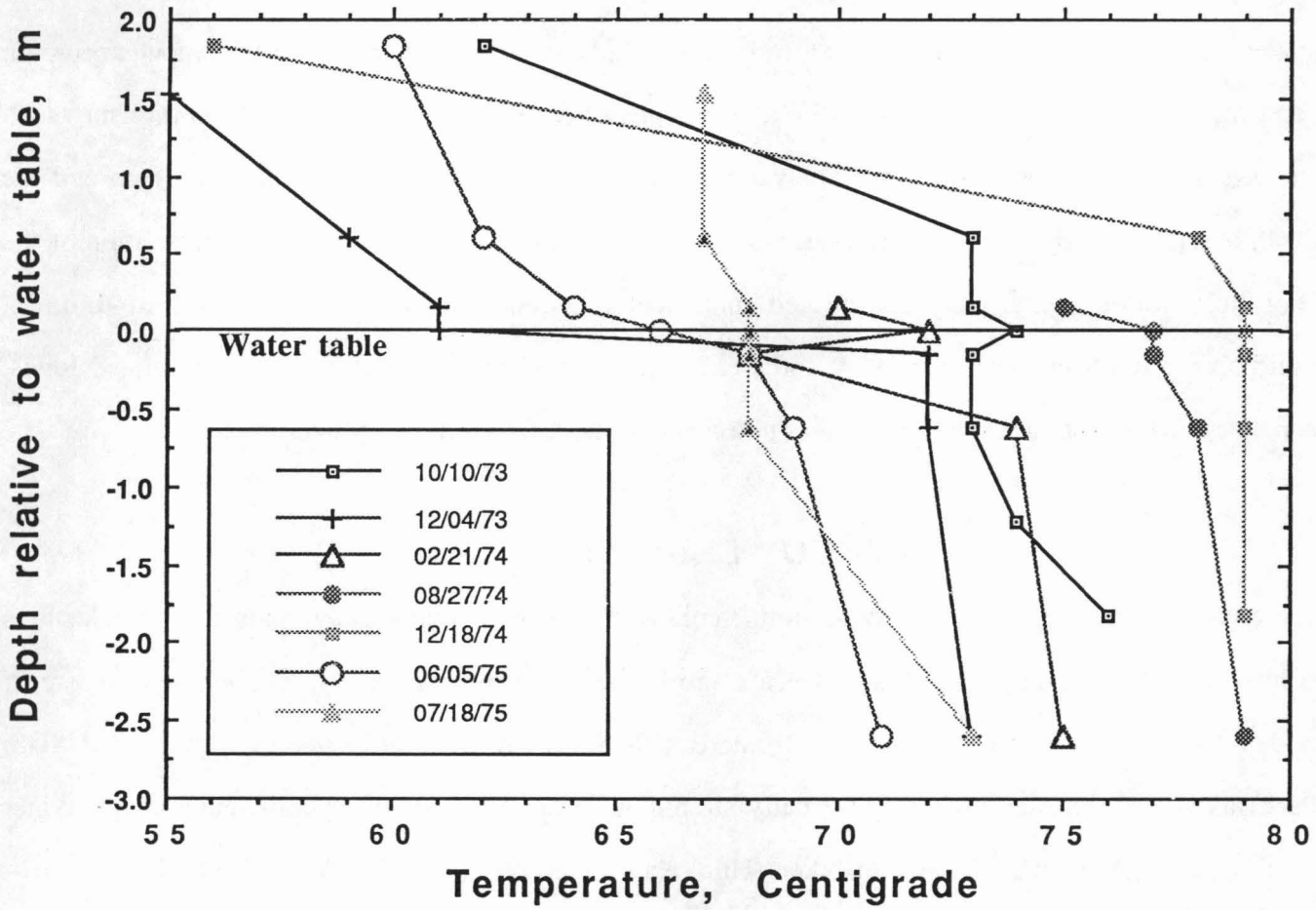

Figure 3. Temperature profiles in the borehole a few meters above and below the regional water level. The lowest air temperatures above the water level were registered for the 12/04/73 profile, measured just two days after 14.6 inches of rain fell in a 3-day period (11/30/73-12/02/73).

Analytical data determined by USGS laboratories for samples from the summit borehole and elsewhere on the Island of Hawaii are given in Tables 3-7. To facilitate comparison of our data, selected chemical and isotopic data from previous investigations are presented in Tables 8-11. In an earlier study (Tilling and Jones, 1990), we also evaluated normative salt assemblages computed from selected analyses using the SNORM computer program (Bodine and Jones, 1986; Jones and Bodine, 1987). The types and proportions of simple salts comprising such normative assemblages for the samples we analyzed are listed in Tables 12-14. Both the raw data and the SNORM salt assemblages demonstrate short-term and long-term temporal variations in the composition of the summit-borehole waters, tentatively interpreted to reflect the combined processes of rainfall dilution, eruptive/intrusive activity in December 1974, and weathering of the host tholeiitic basalts (Tilling and Jones, 1990). A major objective of our continuing studies to test and refine these preliminary interpretations.

ACKNOWLEDGMENTS

The analytical data reported here represent the collective efforts by many individuals and organizations since the initiation of this study more than 15 years ago (!), and to them we want to express our sincere, if somewhat belated, thanks. Charles J. Zablocki (formerly USGS, now retired) and Robert O. Fournier (USGS, Menlo Park) assisted with many of the physically strenuous sampling runs. Our colleagues at the Water Resources Division field offices--Hideo Gushiken (Hilo, Hawaii) and Johnston J.S. Yee (Honolulu, Hawaii)--and Donald Thomas at the University of Hawaii (Hawaii Institute of Geophysics, Honolulu) provided many of the non-borehole samples as well as the relevant field and analytical information about them. John P. Lockwood (USGS, Hawaiian Volcano Observatory) collected the water samples from the summit of Mauna Loa Volcano. The cooperation and assistance of George V. Keller, John C. Murray, and Cathy Skokan--formerly or presently at the Colorado School of Mines--throughout our study are very much appreciated. Finally, we wish to thank Shirley Rettig (formerly USGS, now retired), Roy J. Knight and Hugh Millard (USGS, Denver), and Tyler Coplen (USGS, Reston) for chemical and isotopic analyses; George Keller also kindly furnished us some heretofore unpublished analytical data obtained by Skyline Labs, Inc., Wheat Ridge, Colorado. USGS colleagues Terry Keith and Michael Thompson, both in located in Menlo Park, reviewed an earlier version of this report and offered constructive comments and suggestions toward its improvement.

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TABLE 1. INFORMATION ON WATER SAMPLES FROM SUMMIT BOREHOLE, KILAUEA VOLCANO, HAWAII

[All samples from this study except for samples 32 and 50]

Sample No.	Date Collected	Depth* (m)	Temp. (°C)	Field pH	Remarks**
KBW-1	09/04/73	2	71	7.0-7.5	
KBW-2	09/18/73	2	---	7.0-7.5	
KBW-3	10/10/73	2	75	7.0-7.5	
KBW-4	12/04/73	2	73	---	Also contains much suspended dark, magnetic material
KBW-5	02/21/74	2	74	---	
KBW-6	08/27/74	2	79	---	
32	09/11/74	0-2 interval	75	7.3	McMurtry et al. (1977, Table 1)
50	12/15/74	30.5	83	6.9	McMurtry et al. (1977, Table 1)
KBW-7	12/18/74	0	79	---	Top of water column
KBW-8	12/18/74	30.5	---	---	Perhaps comparable to sample 50 of McMurtry et al. (1977, Table 1)
KBW-9	06/05/75	2	71	---	
KBW-10	07/18/75	0-2.4 interval	73	---	
KBW-11	07/24/75	0	70	7.0-7.5	Top of water column
KBW-12	04/17/76	0-15 interval	---	---	Sample represents a mixture of waters in depth interval
KBW-13	04/19/76	0-15 interval	---	---	Sample represents a mixture of waters in depth interval

* Depth is relative to local water table (488 m below ground surface).
** All samples contain varying amounts of suspended drilling mud.

TABLE 2. INFORMATION ON OTHER SAMPLES FROM THE ISLAND OF HAWAII ANALYZED IN THIS STUDY

Sample No.	Date(s) Collected	Temp. (°C)	Field pH	Lab. pH	Remarks
PSM-1	05/16/74	18	---	7.60	Pumped well water from Puna Sugar Mill, Olaa
WR-1	03/10/75	---	---	8.31	Wright Road borehole # 1, Volcano Village; total depth, 105 m, water level, 99 m
WR-3	03/10/75	---	---	7.94	Wright Road borehole # 3, Volcano Village; total depth, 111 m, water level, 101 m
WR-4	03/10/75	---	---	7.93	Wright Road borehole # 4, Volcano Village; total depth, 99 m, water level, 79 m
HVO-1	04/24/76-04/27/76	---	---	4.25	Aggregate sample of rainfall collected at the Hawaiian Volcano Observatory in the period April 24-27, 1976
HVO-2	05/03/76-06/01/76	---	---	5.04	Aggregate sample of rainfall collected at the Hawaiian Volcano Observatory on May 3, 20, 21, and June 1, 1976.
ERZ-1	07/22/76	---	---	5.52	Side-stream sample (mixture of brine and steam condensate) taken during extended production testing of geothermal well HGP-A, lower east-rift zone, Kilauea Volcano
MLS-1	08/04/76	---	---	6.35	Permafrost crack water, rim of Mokuaweoweo caldera, summit of Mauna Loa Volcano
HILEA-1	08/10/76	15	7.2	7.03	Hilea Gulch tributary, near Honuapo, SE flank of Mauna Loa Volcano; discharge 0.18 cfs at time of sampling
WLK-1	10/19/76	16	---	7.01	Wailuku River, near Humu'ula station 7017.5, saddle area between Mauna Kea and Mauna Loa Volcanoes; stream not flowing at time of collection--estimated date of stoppage ~1 week before sampling
MLS-2	06/06/78	---	---	---	Permafrost crack water, rim of Mokuaweoweo caldera, summit of Mauna Loa Volcano

TABLE 3. CHEMICAL ANALYSES OF WATER SAMPLES FROM SUMMIT BOREHOLE, KILAUEA VOLCANO, HAWAII

[Concentrations of chemical constituents in mg/L; analysts: Shirley Rettig for element concentrations, Tyler B. Coplen for isotopic ratios]

[All samples from this study except for samples 32 and 50, data for which are from McMurtry et al. (1977, Table 1)]

Sample No.	Date Collected	Ca	Mg	Na	K	CO_3	HCO_3	SO_4	Cl	F	B	PO_4	SiO_2	TDS	Sp. Cond.	Lab. pH	$\delta^{18}O$ (‰ SMOW)	δD
KBW-1	09/04/73	49	39	740	90	20	274	1560	84	0.9	0.93	0.03	67	2780	3460	8.50	---	---
KBW-2	09/18/73	47	43	720	104	30	248	1570	84	0.8	1.00	0.05	109	2830	3570	8.50	-4.57	-26.5
KBW-3	10/10/73	52	42	710	116	24	194	1620	95	0.8	1.07	0.01	91	2850	3670	8.50	-4.56	-25.0
KBW-4	12/04/73	36	22	545	47	31	366	972	54	1.0	0.46	0.07	14	1900	2650	8.65	-4.60	-25.8
KBW-5	02/21/74	106	51	700	124	35	338	1660	95	0.8	1.09	0.03	135	3070	3770	8.2	-4.83	-28.6
KBW-6	08/27/74	62	65	750	140	---	295	1860	100	1.5	1.09	---	140	3260	3880	8.1	---	---
32	09/11/74	---	---	---	---	---	---	---	---	---	---	---	159	---	---	---	-4.7	-31
50	12/15/74	---	---	---	---	---	---	---	---	---	---	---	180	---	---	---	-4.7	-29
KBW-7	12/18/74	63	70	759	142	---	270	1960	110	1.5	1.32	---	119	3360	---	8.2	---	---
KBW-8	12/18/74	49	64	769	142	---	150	1900	110	1.5	1.59	---	122	3230	---	8.25	---	---
KBW-9*	06/05/75	72	87	730	111	---	792	1490	83	1.9	0.77	0.02	89	3050	---	7.55	-4.20	-27.5
KBW-10*	07/18/75	101	72	537	90	---	985	925	60	1.0	0.49	0.00	121	2390	3000	7.95	-4.20	-28.5
KBW-11*	07/24/75	104	69	490	66	---	1030	796	50	1.0	0.46	0.02	101	2180	2720	7.97	-4.62	-29.5
KBW-12	04/17/76	104	107	221	44	---	1040	285	14	1.3	0.14	---	98	1390	1790	8.05	-5.03	-30.0
KBW-13	04/19/76	106	110	214	43	---	1080	269	12	1.3	0.14	---	94	1380	1730	8.0	-4.55	-31.0

* Notes: (1) KBW-9: Sr, 1.9; Li, 0.10; NH_4^+, 0.15; Fe (T), 0.02; Mn (T), 0.57.
(2) KBW-10: Sr, 0.7; Li, 0.07; Fe (T), 0.01; Mn (T), 0.10.
(3) KBW-11: Sr, 0.8; Li, 0.07; Fe (T), 0.04; Mn (T), 0.12.

TABLE 4. CHEMICAL ANALYSES OF OTHER WATER SAMPLES COLLECTED FOR THIS STUDY

[Concentrations of chemical constituents in mg/L; analysts: Shirley Rettig for element concentrations, Tyler B. Coplen for isotopic ratios]

Sample No.	Date Collected	Ca	Mg	Na	K	HCO_3	SO_4	Cl	F	B	PO_4	SiO_2	TDS	Sp. Cond.	Lab. pH	$\delta^{18}O$ (‰ SMOW)	δD (‰ SMOW)
PSM-1	05/16/74	5.1	2.8	6.5	2.0	35	8.2	3.5	0.1	0.12	0.09	36	82	88	7.6	-3.78	-18.4
WR-1*	03/10/75	18	12	7.1	2.3	129	3.0	3.0	0.2	0.01	0.00	50	159	212	8.31		
WR-3*	03/10/75	22	13	6.8	1.4	154	2.2	2.2	0.2	0.00	0.04	54	178	250	7.94	-4.49	-21.1
WR-4*	03/10/75	17	11	6.2	1.7	126	2.8	2.3	0.2	0.00	0.11	52	155	207	7.93	-4.61	-21.3
HVO-1	04/24/76-04/27/76	0.5	0.1	2.6	0.1	0	7.3	1.2	---	---	---	1.0	---	---	4.25	-4.89	-24.5
HVO-2	05/03/76-06/01/76	0.2	0.0	0.2	0.0	1	0.7	0.8	---	---	---	0	---	---	5.04	---	-20.9
ERZ-1*	07/22/76	35	0.4	552	70	136	87	950	0.4	0.83	0.54	296	2190	2930	5.52	---	---
MLS-1*	08/04/76	4.2	1.1	5.3	2.0	12	19	3.6	0.2	0.00	0.02	12	56	100	6.35	-12.5	-91.5
HILEA-1	08/10/76	3.8	2.2	3.3	0.7	19	6.7	4.4	0.1	0.02	---	14	50	56	7.03	---	---
WLK-1*	10/19/76	1.9	1.9	2.0	0.8	18	0.2	1.6	---	0.02	---	9.2	18	33	7.01	---	---
MLS-2	06/06/78	---	---	---	---	---	---	---	---	---	---	---	---	---	---	-12.53	-91.5

* Notes:
(1) WR-1: Sr, 0.15; NH_4^+, 0.24.
(2) WR-3: Sr, 0.14; NH_4^+, 0.09.
(3) WR-4: Sr, 0.12; NH_4^+, 0.07.
(4) ERZ-1: NO_3, 1.2; Sr, 0.2; Li, 0.2; Fe (T), 3.3; $S^=$as H_2S, 42.
(5) MLS-1: NO_3, 0.4; Sr., 0.0; Li, 0.0; Fe (T), 0.02, $S^=$as H_2S, 0.06.
(6) WLK-1: Fe (T), 0.07.

TABLE 5. INSTRUMENTAL NEUTRON-ACTIVATION ANALYSES (INAA) ANALYSES OF DRILLING MUD SAMPLES FROM SUMMIT BOREHOLE, KILAUEA VOLCANO, HAWAII

[Concentrations in ppm; -.-, below detection level or poor counting statistics. Analysts: R.J. Knight and H.T. Millard, Jr.]

	Drilling mud (original, dry)	Drilling mud (filtered from water sample/dried)				Slurries (mud + water)			
Sample No.	ZTEL-7[1]	KELL-3	KELL-5	KELL-7	KELL-9	KELL-13	KELL-14[2]	KELL-15	KELL-16[2]
Date Collected	Before 06/15/73	06/28/73	07/03/73	07/05/73	07/08/73	07/11/73	07/11/73	07/11/73	07/11/73
Cs	0.392	0.395	0.376	0.396	0.395	0.016	-.-	0.010	-.-
Rb	14.4	13.6	15.7	11.4	12.3	-.-	0.6	-.-	-.-
Ba	382	355	381	385	353	261	22	284	22
Sr	246	246	229	257	251	15	-.-	25	-.-
K	4410	3940	3940	4040	3890	-.-	-.-	254	-.-
Na	19700	21200	21600	21300	21900	492	326	485	179
Th	33.7	31.6	33.9	34.0	32.8	0.8	0.3	0.6	0.1
U	13.0	12.1	13.0	12.2	11.6	0.3	-.-	-.-	-.-
La	49.7	46.1	48.9	47.8	48.1	1.4	-.-	1.2	0.1
Ce	95.3	89.4	100.0	97.7	97.9	2.6	1.1	15.1	6.9
Nd	42.6	39.4	41.9	41.8	40.0	1.0	-.-	2.9	-.-
Sm	9.4	8.8	9.8	8.9	9.0	0.3	0.1	-.-	-.-
Eu	0.697	0.668	0.713	0.712	0.701	0.043	0.009	0.026	0.004
Gd	10.2	8.3	9.4	9.9	8.8	-.-	-.-	-.-	-.-
Tb	1.42	1.32	1.45	1.45	1.49	0.06	0.02	0.03	-.-
Dy	8.29	8.58	9.34	8.81	7.92	0.27	0.12	0.30	0.02
Tm	0.52	0.53	0.71	0.56	0.52	-.-	-.-	0.06	-.-
Yb	3.27	3.22	3.52	3.45	3.34	0.07	0.02	0.07	-.-
Lu	0.553	0.529	0.579	0.559	0.582	0.017	-.-	0.018	-.-
Ta	3.42	3.25	3.46	3.43	3.37	0.09	0.04	0.07	-.-
Zr	260	251	273	265	260	9	3	5	-.-
Hf	7.07	6.86	7.31	7.41	7.08	0.18	0.07	0.69	-.-
Sb	0.968	0.937	0.973	0.955	0.977	0.063	0.023	0.053	0.025
Sc	4.75	4.56	4.84	4.73	4.59	0.45	0.08	0.28	0.02
Mn	223	215	221	204	230	23	5	19	2
Fe	25000	23900	25300	25000	24700	2000	577	1180	181
Cr	3.79	3.39	3.09	3.17	3.45	10.1	1.1	5.66	1.03
Co	1.4	66.1	42.8	30.9	27.4	4.3	0.5	2.1	0.6

Notes:
[1] Collection date unknown but before 06/15/73.
[2] For samples KELL-14 and KELL-16, lid of container loose--samples have undergone partial evaporation.

TABLE 6. INSTSRUMENTAL NEUTRON-ACTIVATION ANALYSES (INAA) OF WATER AND DRILLING MUD SAMPLES FROM SUMMIT BOREHOLE, KILAUEA VOLCANO, HAWAII

[Concentrations in ppm; -.-, below detection level or poor counting statistics. Analysts: R.J. Knight and H.T. Millard, Jr.]

	Drilling mud (original, dry)	Water samples from borehole						Drilling water
Sample No.	ZTEL-7*	KELL-1*	KELL-2	KELL-4	KELL-6	KELL-8	KELL-10	PSC*
Date Collected	Before 06/15/73	06/15/73	06/23/73	06/28/73	07/03/73	07/05/73	07/08/73	05/16/74
Cs	0.392	0.018	0.024	0.006	-.-	-.-	-.-	-.-
Rb	14.4	0.3	-.-	0.5	-.-	0.5	-.-	0.3
Ba	382	9.0	37.9	7.3	-.-	4.8	16.3	-.-
Sr	246	-.-	-.-	-.-	-.-	-.-	-.-	0.3
K	4410	-.-	-.-	-.-	-.-	41	-.-	40
Na	19700	31	24	33	25	33	54	27
Th	33.7	0.01	0.02	-.-	-.-	0.01	0.01	-.-
U	13.0	-.-	-.-	-.-	-.-	-.-	-.-	-.-
La	49.7	0.16	-.-	0.23	-.-	-.-	-.-	-.-
Ce	95.3	-.-	-.-	-.-	-.-	-.-	-.-	-.-
Nd	42.6	-.-	-.-	-.-	-.-	-.-	-.-	1.6
Sm	9.4	-.-	-.-	-.-	-.-	-.-	-.-	-.-
Eu	0.697	0.001	-.-	0.002	0.002	0.002	-.-	0.002
Gd	10.2	-.-	-.-	-.-	-.-	-.-	-.-	-.-
Tb	1.42	-.-	-.-	0.014	-.-	-.-	-.-	-.-
Dy	8.29	-.-	-.-	-.-	-.-	-.-	-.-	-.-
Tm	0.52	0.06	-.-	-.-	0.06	-.-	0.06	-.-
Yb	3.27	-.-	-.-	-.-	0.02	-.-	-.-	0.02
Lu	0.553	-.-	-.-	-.-	-.-	0.003	-.-	-.-
Ta	3.42	-.-	-.-	0.004	-.-	-.-	-.-	0.004
Zr	260	-.-	-.-	-.-	-.-	-.-	0.9	-.-
Hf	7.07	-.-	-.-	0.005	-.-	-.-	-.-	-.-
Sb	0.968	-.-	0.003	-.-	0.001	-.-	0.001	0.193
Sc	4.75	0.004	0.002	0.001	0.003	0.002	0.001	0.004
Mn	223	0.15	-.-	0.06	0.02	-.-	0.14	-.-
Fe	25000	-.-	8.4	17.1	-.-	11.5	-.-	16.3
Cr	3.79	0.13	0.56	0.14	0.27	0.29	0.30	0.42
Co	1.35	0.089	4.500	1.020	0.278	0.066	0.111	0.022

* Notes: (1) Collection date of sample ZTEL-7 unknown but sometime before 06/15/73.
(2) KELL-1 collected before contamination with cobalt in tracer experiment.
(3) PSC is from same well as PSM-1, source of the drilling water.

TABLE 7. INSTRUMENTAL NEUTRON-ACTIVATION ANALYSES (INAA) OF WATER AND DRILLING MUD SAMPLES FROM SUMMIT BOREHOLE, KILAUEA VOLCANO, HAWAII

[Concentrations in ppm; -.-, below detection level or poor counting statistics.
Analysts: R.J. Knight and H.T. Millard, Jr.]

	Drilling mud (original, dry)	Water samples from borehole					Drilling water
Sample No.	ZTEL-7*	ZTEL-1	ZTEL-2	ZTEL-3	ZTEL-4	ZTEL-5	PSC*
Date Collected	Before 6/15/73	9/04/73	09/18/73	10/10/73	12/04/73	02/21/74	05/16/74
Cs	0.392	-.-	-.-	-.-	-.-	-.-	-.-
Rb	14.4	0.3	0.4	0.4	0.5	0.4	0.3
Ba	382	6.1	3.3	11.0	3.9	5.3-.-	-.-
Sr	246	-.-	2.4	-.-	3.8	-.-0.3	0.3
K	4410	238	243	-.-	-.-	190	40
Na	19700	1710	1120	880	669	881	27
Th	33.7	-.-	-.-	-.-	-.-	-.-	-.-
U	13.0	-.-	-.-	-.-	-.-	-.-	-.-
La	49.7	0.24	0.16	0.04	-.-	0.27	-.-
Ce	95.3	-.-	-.-	-.-	-.-	-.-	-.-
Nd	42.6	-.-	-.-	-.-	-.-	0.3	1.6
Sm	9.4	-.-	-.-	-.-	-.-	-.-	-.-
Eu	0.697	0.002	0.004	-.-	0.002	-.-	0.002
Gd	10.2	-.-	-.-	-.-	-.-	-.-	-.-
Tb	1.42	-.-	-.-	-.-	0.0058	0.0073	-.-
Dy	8.29	0.06	-.-	0.05	-.-	-.-	-.-
Tm	0.52	-.-	-.-	-.-	-.-	-.-	-.-
Yb	3.27	-.-	-.-	-.-	0.02	-.-	0.02
Lu	0.553	-.-	-.-	-.-	-.-	0.003	-.-
Ta	3.42		-.-	-.-	0.087	0.006	0.004
Zr	260	-.-	-.-	-.-	-.-	-.-	-.-
Hf	7.07	0.005	0.005	-.-	0.007	-.-	-.-
Sb	0.968		0.013	0.009	0.020	0.013	0.193
Sc	4.75		0.004	0.002	0.001	0.003	0.004
Mn	223	-.-	-.-	0.08	0.44	0.72	-.-
Fe	25000	24.0	23.4	-.-	18.1	16.9	16.3
Cr	3.79	0.18	0.14	-.-	0.24	0.26	0.42
Co	1.35	0.022	0.025	0.004	0.037	0.034	0.022

* Notes: (1) Collection date of sample ZTEL-7 unknown but sometime before 06/15/73.
(2) PSC is from same well as PSM-1, source of the drilling water.

TABLE 8. PARTIAL ANALYSES OF WATER, FLUIDS, AND MUD SAMPLES FROM SUMMIT BOREHOLE, KILAUEA VOLCANO, HAWAII

[Concentrations of constituents in mg/L; -.-, not determined. Analytical data obtained by Skyline Labs, Inc., Wheat Ridge, Colorado]

[Provided by George V. Keller, Consultant, Golden, Colorado 80401]

Sample No.	Date Collected	Ca	Mg	Na	K	Co	Cl	F	Material
KELL-1	06/15/73	-.-	-.-	-.-	-.-	0.1	-.-	-.-	drill water*
KELL-2	06/23/73	-.-	-.-	-.-	-.-	5.2	-.-	-.-	drill water
KELL-3	06/28/73	-.-	-.-	-.-	-.-	3.0	-.-	-.-	mud
KELL-4	06/28/73	-.-	-.-	-.-	-.-	3.4	-.-	-.-	drill water
KELL-5	07/03/73	-.-	-.-	-.-	-.-	1.6	-.-	-.-	mud
KELL-6	07/03/73	-.-	-.-	-.-	-.-	1.7	-.-	-.-	drill water
KELL-7	07/05/73	330	135	1300	34	2.1	4.6	-.-	mud
KELL-8	07/05/73	5.8	3.4	12	2.4	1.9	3.4	0.1	drill water
KELL-9	07/08/73	360	130	1250	32	2.2	5.0	-.-	mud
KELL-10	07/08/83	5.5	4.1	14	2.4	1.5	3.7	0.2	drill water
KELL-11	07/10/73	52	11	155	21	1.2	30	0.4	well fluid
KELL-12	07/10/73	88	28	400	13	0.5	100	-.-	formation fluid, 3733'
KELL-13	07/11/73	76	25	180	12	1.1	22	0.4	well fluid
KELL-14	07/11/73	34	10	230	8.1	0.1	55	1.0	formation fluid, 3400'
KELL-15	07/11/73	125	37	240	16	1.3	15	0.4	well fluid
KELL-16	07/11/73	25	7.0	120	9.3	0.5	50	0.7	formation fluid, 3100'

* Before contamination by spiking with cobalt in tracer experiment; all other drill water samples collected after spiking.

TABLE 9. SELECTED CHEMICAL ANALYSES OF HAWAII GROUNDWATERS (From McMurtry et al., 1977, Table 2)

[Concentrations of chemical constituents in ppm]

USGS Well No.	Name	Ca	Mg	Na	K	CO_3	HCO_3	SO_4	Cl	F	NO_3	SiO_2	TDS	pH
						Puna District Wells*								
9-11	Pahoa 1	5.0	4.2	20.0	2.6	0	51	6.8	20.0	0.3	0.1	54	137	7.7
9-5A,B	Pahoa 2	3.3	3.3	16.5	3.4	0	51	12.5	6.0	0.6	0.4	52	123	7.5
SH 9	Kapoho Cone	80	51	73	10.5	2	551	6.8	84	0.3	13	41	653	7.7
9-9	Malama-ki	182	324	3090		0	262	681	5850	1.5	0.51	59	11700	6.9
9-7	Keauohana	6.6	3.3	54	3.8	0	42	22	70	0.2	0.0	41	221	7.3
9-10	Pulama	16	31	170	8.5	0	54	65	345	0.1	0.3	72	838	7.4
SH 7	Olaa Mill	6.0	2.7	5.8	2.4	0	38	5.5	4.0	0.1	2.8	40	88	7.0
9A,B	Olaa Mill	4.8	3.5	8.7	1.8	0	33	8.4	7.3	0.2	0.4	21	72	7.4
9-2	Keaau Orchard	6.5	5.9	39	3.7	0	44	12	58	0.1	3.6	33	183	7.3
9-12	Keaau Orchard	8.9	13.6	90	5.6	0	42	25	156	0.1	3.1	33	355	6.8
						Other Hawaii Island Wells**								
SH 8	Pahala Mill	6.6	3.6	7.2	1.0	0	43	10	3.5	0.2	0.9	42	96	7.2
---	Ninole Springs	9.6	14	84	4.6	0	42	26	151	0.2	1.0	44	354	7.2
10	Honuapo Mill	33	86	680	24	0	46	169	1240	0.2	0.0	43	2300	7.0
12-4,8	Keei	12	10	61	5.0	4	45	23	99	0.2	2.3	41	292	7.5
12-5,6	Kahaluu	6.4	4.4	16	4.8	0	62	9.0	11	0.3	3.7	48	133	7.2
12	Kailua	31	27	247		0	56	79	459	0.2	1.5	43	1079	7.5
12-7	Kaupulehu	28	73	260	13	0	432	68	370	2.1	7.3	78	1110	7.7
15	Mauna Kea Beach Hotel	21	34	216	15	0	94	62	390	0.3	3.2	51	838	7.6
16	Kawaihae	32	32	132	14	0	105	52	253	0.2	3.6	84	728	7.1
8-2	Hilo Electric	8.4	2.9	6.9	1.8	0	47	2.6	6.5	0.1	0.0	55	107	7.2

Notes:

* Wells at Olaa Mill and Keaau Orchard penetrate lavas of Mauna Loa Volcano; the other wells in the Puna District are in lavas of Kilauea Volcano.

** Wells at Pahala Mill, Ninole Springs, Hilo Electric, and Keei are in lavas of Mauna Loa Volcano; wells at Kahaluu, Kailua, and Kaupulehu are in lavas of Hualalai Volcano; well no. 15 is on Mauna Kea Volcano; and well no. 16 is on Kohala Volcano.

TABLE 10. PREVIOUSLY PUBLISHED INFORMATION ON OTHER WATER SAMPLES FROM THE ISLANDS OF HAWAII, MAUI, AND OAHU

[From McMurtry et al., 1977, Table 1]

Sample No.	Name	Date Collected	Temp (°C)[1]	Salinity (‰)	SiO_2 (ppm)[2]	$\delta^{18}O$ (‰ SMOW)	δD (‰ SMOW)
	ISLAND OF HAWAII						
1	Pohoiki Spring	01/29/74	35	8.2	96	-2.7	-14
2	Allison Spring	01/29/74	31	11.9	100	-2.2	-12
3	Kapoho Landing Strip Well	01/29/74	38	1.1	56	-3.2	-15
40	Kapoho Landing Strip Well	12/13/74	34	1.4	53	-3.0	-12
41	Kapoho Landing Strip Well	12/13/74	34	1.2	70	-3.1	-15
4	Pahoa Well 2	01/30/74	23*	0.2	60	-3.8	-18
5	Kapoho Cone Shaft	01/30/74	25	0.7	56	-3.6	-19
6	Keauohana Well	01/30/74	24*	0.5	48	-3.4	-16
27	Olaa Mill Well	06/11/74	22*	0.1	39	-3.9	-20
8	Pulama Well	01/31/74	28	0.6	59	-4.0	-21
9	Allison Well	01/31/74	38	2.6	53	-3.3	-17
10	Malama-Ki Well	01/31/74	56	22.8	90	-1.7	-9
38	Malama-Ki Well	12/13/74	53	19.5	63**	-1.6	-9
39	Malama-Ki Well	12/13/74	54	20.1	54**	-1.5	-10
7	Geothermal test hole 2	01/30/74	83	< 0.1	0.0	-4.5	-10
42	Geothermal test hole 2	12/14/74	86	0.1	1.1	-2.4	-4
31	Geothermal test hole 3	09/10/74	93	7.2	178	-2.4	-13
44	Geothermal test hole 3	12/14/74	95	6.8	184	-2.5	-12
45	Geothermal test hole 3	12/14/74	88	6.5	187	-2.5	-12
57	Geothermal test hole 3	12/16/74	86	7.1	184	-2.5	-12
32	Kilauea Research Drill Hole	09/11/74	75	2.9	159	-4.7	-31
50	Kilauea Research Drill Hole	12/15/74	83	3.0	180	-4.7	-29
11	Palima Well	02/01/74	21*	0.1	54	-6.7	-42

Notes:
1 Temperatures marked by * were measured directly after sample recovery; all other temperatures were measured *in-situ*.
2 Questionable values are indicated by **; these samples produced a blue compound during analysis.

TABLE 10. Continued

Sample No.	Name	Date Collected	Temp (°C)	Salinity (‰)	SiO_2 (ppm)	$\delta^{18}O$ (‰ SMOW)	δD (‰ SMOW)
	ISLAND OF HAWAII						
12	Pahala Mill Shaft	02/28/74	--	0.1	49	-5.4	-31
13	Ninole Springs Well	02/01/74	21*	0.5	48	-4.6	-24
14	Honuapo Mill Well	02/20/74	--	1.3	48	-3.9	-21
23	Keei Well	06/10/74	21*	0.4	53	-4.3	-21
24	Kahaluu Well	06/10/74	22*	0.2	52	-5.0	-29
25	Kailua Well	06/10/74	25	1.5	40	-4.1	-21
18	Mauna Kea Beach Hotel Well	02/02/74	27*	1.0	66	-5.1	-27
16	Kawaihae Well	02/02/74	31*	0.6	8	-4.2	-20
26	Hilo Electric Well	06/11/74	24*	0.2	40	-3.3	-15
15	Rain, Cloud Physics Obs., Hilo	02/08/74	--	< 0.1	0.0	-1.8	-1
28	Rain, Cloud Physics Obs., Hilo	06/14/74	--	0.1	0.0	-2.1	-6
29	Rain, Cloud Physics Obs., Hilo	06/28/74	--	< 0.1	0.5	-1.2	0
30	Rain, Cloud Physics Obs., Hilo	07/15/74	--	0.4	0.3	-1.4	-4
	ISLAND OF MAUI						
33	Olowalu Shaft	09/13/74	25	3.1	56	-4.0	-19
34	Ukumehame Shaft	09/13/74	32	1.3	66	-4.1	-21
35	Olowalu Well	09/13/74	26*	1.7	56	-3.6	-15
36	Pioneer Mill Well	09/13/74	24	5.4	58	-3.6	-16
37	Iao Valley Well	09/13/74	24	0.1	15	-4.0	-16
	ISLAND OF OAHU						
58	Lualualei Well	07/30/75	27	0.8	74	-4.2	-21
59	Nanakuli Shaft	08/01/75	28	1.0	101	-5.1	-28

Notes:
1 Temperatures marked by * were measured directly after sample recovery; all other temperatures were measured *in-situ*.
2 Questionable values are indicated by **; these samples produced a blue compound during analysis.

TABLE 11. SELECTED CHEMICAL ANALYSES OF HAWAII GROUNDWATERS (From Swain, 1973, Appendix A)

[Concentrations of chemical constituents in mg/L]

Location	Well. No.	Date Collected	Ca	Mg	Na	K	CO_3	HCO_3	SO_4	Cl	F	NO_3	SiO_2	TDS (calc.)	Cond.	pH	Temp. (°C)
Naalehu	0335-01	05/14/71	6.0	4.8	12	1.5	---	44	14	8.0	0.3	1.9	45	114	128	7.0	19.5
Honuapo	0533-01	04/12/72	33	86	680	24	---	46	169	1240	0.2	0.0	43	2230	4180	7.0	19.0
"	0533-02	04/12/72	20	44	320	14	---	42	86	580	0.1	0.7	43	1130	2120	7.1	19.0
"	0533-03	04/12/72	18	38	272	12	---	41	75	500	0.2	1.7	43	980	1850	7.0	19.0
"	0632-01	04/12/72	17	33	245	11	---	44	66	440	0.2	1.3	41	876	1620	7.3	19.0
Punaluu	0830-01	04/12/72	9.6	16	118	5.5	---	34	37	205	0.2	0.7	32	440	830	7.1	19.0
Ninole	0831-01	04/12/72	9.2	12	80	4.4	---	43	24	136	0.2	1.2	41	329	561	7.3	19.0
"	0831-02	03/01/72	10	16	88	4.8	---	40	28	165	0.2	0.8	46	378	681	7.1	18.5
Pahala	1128-01	04/13/72	6.6	3.6	7.2	1.0	---	43	10	3.5	0.2	0.9	42	96	99	7.2	19.0
Pulama	2102-01	12/06/63	16	31	170	8.5	---	54	65	345	0.1	0.3	72	734	---	7.4	---
Kalapana	2487-01	03/03/72	6.6	3.3	54	3.8	---	42	22	70	0.2	0.0	41	221	344	7.3	23.0
Keei	2753-01	12/17/58	22	8.5	54	---	34	10	30	90	0.2	0.4	24	268	---	9.4	---
		03/14/68	15	12	60	6.1	---	59	19	93	0.2	4.6	31	269	---	7.4	---
		06/02/70	20	11	60	5.0	---	49	23	108	0.0	4.8	45	300	---	7.6	---
		03/16/72	9.4	11	64	4.3	---	47	22	107	0.4	1.0	50	292	474	7.3	19.0
"	2753-02	05/16/63	7.6	8.9	68	2.0	---	49	28	106	0.3	1.1	49	295	---	7.0	---
		03/20/67	6.1	8.2	53	7.5	---	49	14	72	0.2	1.9	36	223	---	7.3	---
		06/02/70	8	8.2	54	5.0	---	49	20	89	0.0	3.6	44	265	---	7.6	---
		03/16/72	9.6	12	77	4.8	---	44	25	129	0.3	1.3	52	332	555	6.7	19.0
Malama-ki	2783-01	09/06/62	182	324	3090	---	---	262	681	5850	1.5	0.5	59	10300	---	6.9	---
Pahoa	2986-01	03/03/72	3.9	3.3	16	3.3	---	51	12	6.0	0.3	0.5	54	124	126	7.6	22.5
"	2986-02	03/03/72	2.7	3.3	17	3.4	---	50	13	6.0	0.8	0.2	50	121	127	7.4	22.5
Kapoho	3080-02	03/15/68	48	26	97	14	---	283	5.5	125	0.3	2.4	44	501	---	7.7	---
		05/22/70	120	96	64	10	---	975	3.8	72	0.2	9.7	39	895	---	7.0	---
		03/03/72	72	31	57	7.6	6	393	11	54	0.3	27	39	498	793	8.4	---
Pahoa	3185-01	05/05/64	4.2	4.8	16	2.0	---	46	6.7	16	0.2	0.2	59	131	---	7.3	---
"	3185-02	05/22/72	5.8	3.6	23	3.2	---	56	6.9	23	0.3	0.0	49	142	165	7.6	---
Kahaluu	3557-01	03/16/72	7.2	4.0	12	2.1	---	49	9.9	7.0	0.3	3.9	49	119	126	7.2	20.0
"	3557-02	03/20/67	5.5	4.8	20	7.5	---	74	8.0	15	0.2	3.4	46	146	---	7.2	---
"	3557-03	02/28/70	6.5	4.0	14	2.2	---	48	9.0	8.5	0.4	4.6	45	117	133	7.8	---
"	3557-04	02/05/71	6.7	4.4	18	2.5	---	46	11	16	0.3	5.4	46	132	162	7.6	20.5
		03/16/72	4.9	5.0	17	2.3	---	52	10	14	0.3	3.5	41	123	147	7.5	20.0
Keaau	3702-01	06/07/72	6.0	2.7	5.8	2.4	---	38	5.5	4.0	0.1	2.8	40	88	87	7.0	23.0

TABLE 11. Continued

Location	Well. No.	Date Collected	Ca	Mg	Na	K	CO_3	HCO_3	SO_4	Cl	F	NO_3	SiO_2	TDS (calc.)	Cond.	pH	Temp. (°C)
Kailua	3758-01	09/14/49	16	28	261	---	---	58	79	460	0.1	3.1	68	943	---	---	---
		11/21/49	15	9.7	292	---	---	71	81	450	0.1	1.3	46	930	---	---	---
		03/11/55	78	35	200	---	---	51	78	485	0.2	0.8	33	935	---	7.8	---
		12/10/58	15	37	236	---	---	44	76	440	0.2	0.8	26	852	---	7.1	---
Keaau	3802-01	03/23/34	1.6	4.3	14	---	---	32	6.1	14	---	---	12	67	---	---	---
		02/03/55	8.1	3.4	6.3	---	---	30	14	4.0	0.2	0.2	20	70	---	7.4	---
		03/03/72	4.6	2.9	5.7	1.8	---	36	5.0	4.0	0.1	0.5	31	73	78	7.4	24.5
"	3802-03	06/07/72	4.8	2.8	5.2	1.9	---	35	5.3	4.0	0.2	0.0	33	74	77	7.0	19.5
"	3802-05	06/07/72	5.5	3.3	5.2	2.1	---	38	5.5	4.0	0.1	1.5	36	81	88	7.4	22.0
Puna	3900-01	03/07/72	6.5	5.9	39	3.7	---	44	12	58	0.1	3.6	33	183	296	7.3	---
"	3900-02	07/15/66	11	20	126	7.0	---	39	34	230	---	2.5	33	482	905	6.3	---
		03/07/72	6.8	7.1	54	4.1	---	44	16	81	0.1	3.6	33	227	380	7.3	19.5
Panaewa	4003-01	03/13/72	7.8	3.3	5.3	1.6	---	50	1.4	4.0	0.1	0.0	37	85	91	7.5	22.0
Hilo	4202-01	11/10/53	38	15	80	---	---	34	32	180	0.2	0.1	28	390	---	7.4	---
		10/12/54	40	16	76	---	---	32	46	186	0.1	0.0	23	402	---	7.4	---
		02/02/60	8.2	12	62	---	---	35	7.6	108	0.0	0.1	8	223	---	6.7	---
"	4203-02	08/20/64	8.0	4.4	10	1.0	---	50	2.5	11	0.0	0.2	33	94	---	7.0	---
"	4203-03	03/02/72	6.0	3.6	7.4	1.8	---	44	2.0	7.5	0.1	0.8	36	86	95	7.1	23.5
"	4203-04	03/27/72	8.4	2.9	6.9	1.8	---	47	2.6	6.5	0.1	0.0	55	107	94	7.2	26.0
Kaupulehu	4858-01	03/10/65	27	77	250	12	---	439	60	370	2.0	8.3	80	1100	---	7.3	---
		03/17/72	28	69	270	13	---	424	75	370	2.2	6.2	76	1120	1920	8.0	20.0
"	4858-02	07/15/68	6.1	7.9	61	0.6	---	73	10	78	0.1	0.0	37	236	---	7.1	---
Kiholo	4953-01	08/11/72	16	26	218	12	---	91	71	340	0.9	3.8	36	768	1390	7.9	22.0
Pepeekeo	5005-01	03/23/72	12	10	7.8	0.6	---	74	17	12	0.1	0.5	45	141	174	7.2	23.0
"	5005-02	06/13/56	9.4	9.0	9.6	---	---	63	7.4	8.0	0.1	5.6	22	102	---	6.2	---
		07/06/70	10	9.6	10	3.0	---	78	0.0	13	---	1.2	12	97	---	6.1	---
"	5005-05	05/03/72	25	33	160	8.5	---	78	45	322	0.1	0.0	23	655	1220	7.7	20.0
Waikoloa	5548-01	10/27/71	28	45	316	24	---	142	97	542	0.3	3.8	56	1180	2130	7.5	29.0
		04/03/72	28	47	330	22	---	142	95	550	0.5	3.1	82	1230	2110	7.6	---
"	5745-01	06/29/70	7.0	11	32	4.0	---	99	15	26	0.3	6.0	56	206	276	8.0	26.5
		07/28/70	8.0	11	30	5.0	---	93	16	30	---	0.0	64	212	---	7.8	---
		04/05/72	8.1	11	33	4.3	---	102	18	26	0.4	3.8	80	234	280	7.5	---
		08/16/72	8.0	9.0	35	4.4	---	104	15	29	0.0	1.2	42	194	---	---	---
Laupahoehoe	5814-01	05/16/72	15	11	37	3.3	---	58	11	74	0.2	0.2	23	203	365	7.1	20.5
Hapuna	5948-01	04/09/70	20	37	250	15	---	95	68	430	0.3	5.3	49	921	1670	7.3	---
Ouli	6048-02	05/??/72	21	34	216	15	---	94	62	390	0.3	3.2	51	838	1500	7.6	26.0

TABLE 11. Continued

Location	Well. No.	Date Collected	Ca	Mg	Na	K	CO_3	HCO_3	SO_4	Cl	F	NO_3	SiO_2	TDS (calc.)	Cond.	pH	Temp. (°C)
(MKB Hotel)	6049-01	05/17/72	21	34	216	15	---	95	62	390	0.3	1.9	51	837	1520	8.1	---
	6049-02	05/17/72	58	119	974	50	---	106	249	1740	0.3	3.8	50	3300	5840	7.8	26.0
	6049-03	05/17/72	58	111	896	46	---	103	236	1610	0.2	3.2	50	3060	5480	7.5	26.0
Ookala	6117-01	07/20/54	34	13	22	---	---	36	31	85	0.1	0.1	24	226	---	7.9	---
		06/22/55	22	6.9	16	---	---	44	21	40	0.0	0.0	28	155	---	6.9	---
		02/27/67	17	21	75	9.5	---	54	17	160	0.1	1.3	25	352	---	7.5	---
		06/16/70	18	21	125	8.0	---	54	36	230	---	0.0	43	507	---	7.3	---
		04/18/72	11	14	78	4.9	---	62	21	135	0.2	1.0	43	338	599	7.6	---
Kawaihae	6147-01	06/25/63	32	33	135	14	---	109	54	250	0.2	2.9	89	663	---	7.3	---
		06/25/63	32	31	128	13	---	101	49	255	0.2	4.2	78	640	1070	6.9	35.8
"	6148-01	03/22/72	24	32	180	13	---	82	42	340	0.3	3.8	66	741	1330	7.8	28.0
		06/20/72	32	30	175	14	---	---	70	340	0.3	0.8	32	694	---	---	---
Paauilo	6321-01	02/28/67	15	21	77	8.8	---	66	20	165	0.2	2.0	27	368	---	7.3	---
		04/18/72	16	19	102	5.6	---	53	29	195	0.1	0.0	37	429	806	7.6	18.0
Halaula	7347-01	07/19/49	8.0	5.5	15	---	---	43	9.6	22	0.1	0.9	42	125	---	---	---
"	7446-01	03/28/72	60	72	450	20	---	98	120	890	0.2	3.7	63	1730	3230	7.2	24.5

TABLE 12. NORMATIVE SIMPLE SALTS (WT. %)* OF WATER SAMPLES FROM SUMMIT BOREHOLE, KILAUEA VOLCANO, HAWAII

[Calculated from data in Table 3 using the computer program SNORM of Bodine and Jones (1986)]

Sample No.	Date Collected	$CaCO_3$	$MgCO_3$	Na_2CO_3	$CaSO_4$	$MgSO_4$	Na_2SO_4	K_2SO_4	Na_2Cl_2
KBW-1	09/04/73	2.7	5.0		2.3		77.5	7.4	5.2
KBW-2	09/18/73	1.3	5.5		4.0		75.5	8.5	5.2
KBW-3	10/10/73		5.0		6.4	0.3	73.0	9.4	5.7
KBW-4	12/04/73	4.8	4.1	7.6			73.2	5.6	4.8
KBW-5	02/21/74	2.5	6.1		8.9		67.7	9.5	5.4
KBW-6	08/27/74		6.5		6.9	1.2	69.9	10.3	5.2
KBW-7	12/18/74		5.7		6.9	2.8	68.9	10.2	5.5
KBW-8	12/18/74		3.4		5.4	5.3	69.9	10.2	5.8
KBW-9	06/05/75	6.2	10.4	3.5			66.9	8.5	4.6
KBW-10	07/18/75	11.2	11.1	11.8			52.6	8.9	4.3
KBW-11	07/24/75	12.7	11.7	14.4			49.9	7.2	3.9
KBW-12	04/17/76	19.6	28.0	16.2			27.1	7.4	1.8
KBW-13	04/19/76	20.1	29.0	16.8			25.3	7.3	1.6

Note: * Total of the weight-percent values may not exactly equal 100 % because of rounding to one decimal.